Recent Results in Mars Relay Network Planning and Scheduling

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Mars will be continuously crowded this decade and beyond with many missions. Along with the current orbiters of Mars Global Surveyor and Odyssey 2001, future Mars missions within the next few years include Mars Exploration Rovers, Mars Express, and Mars Beagle in 2003, Mars Reconnaissance Orbiter in 2005, G. Marconi, Mars Netlanders, Mars Scouts in 2007, and Mars Smart Lander in 2009. At different time periods in the future, these missions are overlapped and previous studies indicate that during such periods existing deep space communication infrastructure cannot handle all Mars communication needs. There has been much coordination between various Mars projects and the Deep Space Network to ensure communication resources are effectively utilized so that valuable science and engineering data from Mars orbiters and landers can be accommodated. A plausible solution is to perform optimal resource allocation for the Mars relay communication network; a network consisting of multiple surface units and orbiters on Mars and the Deep Space Stations. Unlike direct-to-earth, a relay communication, either in real-time or store-and-forward, can increase network science data return, reduce surface unit's direct-to-earth communication demands, and enable communication even when the surface unit is not facing Earth. It is the objective of this paper to take advantage of the relay operation to efficiently plan and schedule the network communications. Our previous results in relay network planning and scheduling include (i) modeling and simulating the overall end-to-end network link capabilities as time-varying resources by incorporating spacecraft dynamics, telecom configurations and other limiting factors such as planet occultation, weather, etc.; (ii) developing mathematical formulations for operational constraints such as daylight operations, one-to-one communication, time for acquisition and calibration, science data volume return requirement, onboard storage capacity, etc; (iii) formulating and solving the Mars relay network planning and scheduling as linear and nonlinear constrained optimization problem. In this paper, we address several issues that arise in Mars relay network operations. Major issues that we investigate include radio frequency interference, surface unit's battery limitations, and data return latency. Particularly, we (a) develop mathematical conditions, based on the geometry of the orbiters and surface units, to identify links with potential radio frequency interference and impose constraints on the links so that the optimal network scheduling is free from interference; (b) impose both the Sun angle constraint and the transmission duration constraint on the surface unit's battery; and (c) associate each orbiter with a latency function that allows the surface unit to judiciously select its orbiter to minimize the data latency. Numerical studies for a sample Mars relay network will also be presented.